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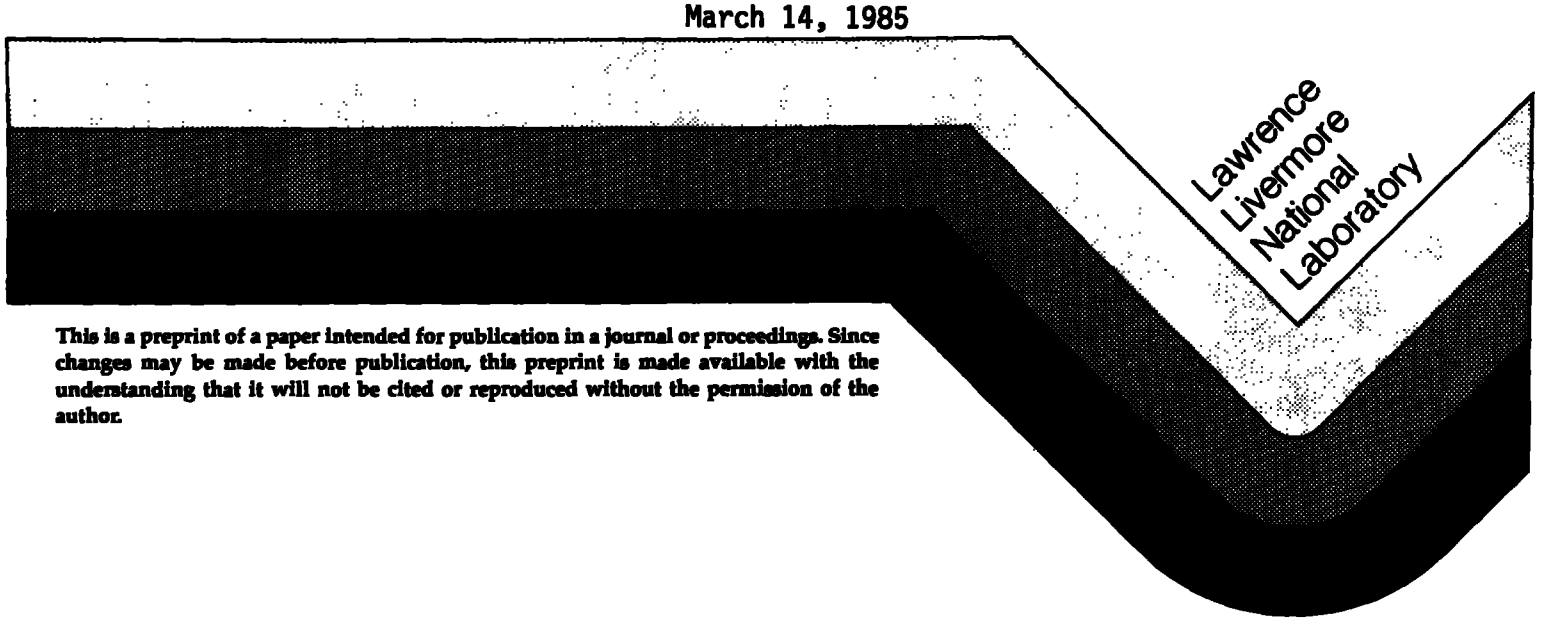

MAXIMUM CURRENT DENSITIES FROM TANDEM HIGH DENSITY SYSTEMS*

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The tandem high-density negative-ion-source system is optimized to identify the largest possible ion concentrations and extracted ion currents. The optimization includes varying the length of the second chamber, varying neutral gas and electron densities, and varying the ratio of atomic to molecular density. The electron excitation processes, e-V and E-V, are taken into account in the first chamber. Negative ions are formed through dissociative attachment in the second chamber.

The set of coupled equations for the fourteen vibrational levels, $H_2(v")$, have been discussed in our previous papers.[1,2] In Fig. 1 is shown the vibrational level distribution versus vibrational level for an electron density in the first chamber appropriate to an optimized system. The upper distribution for each gas density corresponds to an atom density equal to one-tenth the molecular density; for the lower distribution, the atom density is taken equal to the molecular density. For that the portion of the spectrum active in generating negative ions, $v" \geq 5$, the total vibrational excited population represents two to three percent of the molecular concentration.

In Fig. 2 is shown the scaled negative ion density, N(-)R, plotted versus the scaled axial length along the second chamber. The parametric density values shown on the figure are chosen for a system with an R = 10 cm scale length, a scale length appropriate to contemporary tandem high-density systems.[3-5] The solid curves refer to a constant electron density in the second chamber, $n(2) = 10^{12}$ cm^{-3}, while successively increasing the first chamber electron

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density up to a density of 10^{13} cm^{-3}. Having reached this electron density in the first chamber the negative ion density has reached an asymptotic value. Holding the first chamber density constant at the 10^{13} cm^{-3} asymptote and successively increasing the second chamber density generates the dashed solutions. The extracted current density corresponding to the negative ion density is shown on the right-hand scale for 0.3 eV ions.

In Fig. 3 is shown the scaled negative ion density versus second chamber axial length for variations in both electron and gas density. The first chamber the electron density is held fixed at 10^{13} cm^{-3} (R = 10). The successive solutions for $n(2) = 2 \times 10^{12}$ electrons cm^{-3} correspond to successive gas densities equal to 10^{14}, 3×10^{14}, 10^{15}, and 3×10^{15} molecules cm^{-3}. The optimum ion densities and extracted current densities occur for $n(2) = 4\text{-}6 \times 10^{12}$ cm^{-3} and gas densities above 3×10^{14} cm^{-3}. For a minimum value of Z/R = 0.2, the optimum current density is about 30 mA cm^{-2}; for a minimum value of Z/R = 0.1, the current density is almost doubled.

Applying the tandem system scaling law for scaling with R, these current densities approach several hundred mA cm^{-2} as the scale length is reduced from R = 10 cm toward R = 1 cm. In the application of the scaling law, the electron and molecular densities must vary inversely with R.

If the relative atomic density is increased, the extracted current densities are diminished due to enhanced associative detachment. If the atomic density is increased to one-fifth the molecular density the current densities of Figs. 2 and 3 are reduced by a factor of two. If the atomic density becomes equal to the molecular density the extracted current densities are reduced by a factor of six or seven.

Our solutions above have been presented for atomic concentrations ranging from one-tenth up to full molecular concentration. Should it be possible to reduce the atomic concentration to one percent of the molecular concentration,

substantial increases in the extracted current density are possible. For scaled molecular densities of 3×10^{16} molecules cm^{-2}, a reduction of the atomic concentration from one-tenth to one percent of the molecular concentration will increase the current density by approximately a factor of three.

The tandem system has the potential for extracting large current densities. Three critical parameters bear on defining this potential maximum current density: the atomic concentration, the minimum Z/R value for the second chamber, and a minimum practical scale length, R.

References

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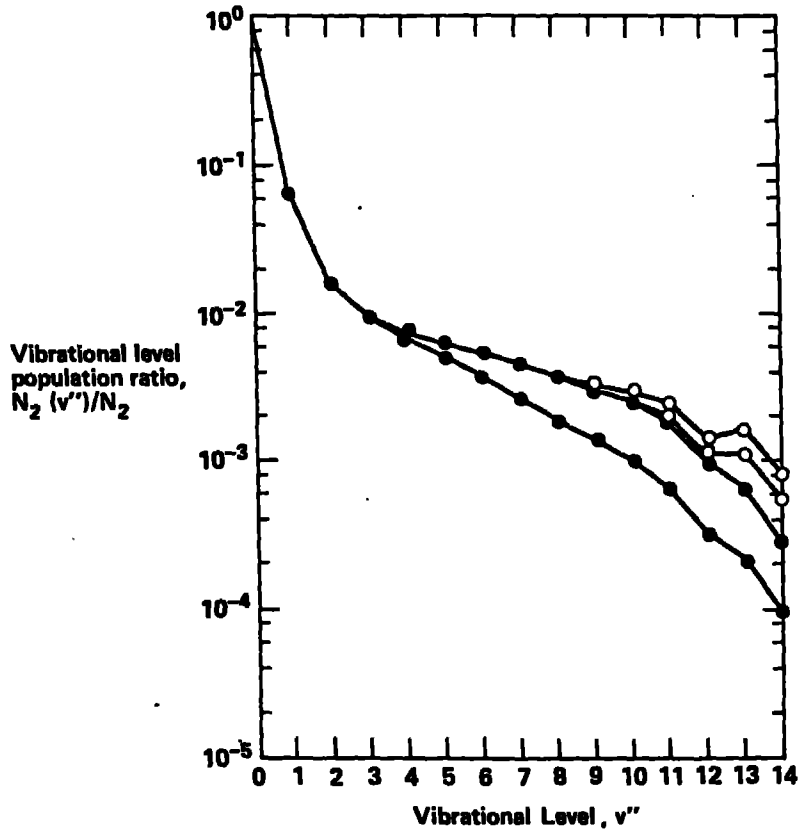
Vibrational level population ratio, N_2 (v'')/N_2
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Vibrational Level, v''

Fig. 1

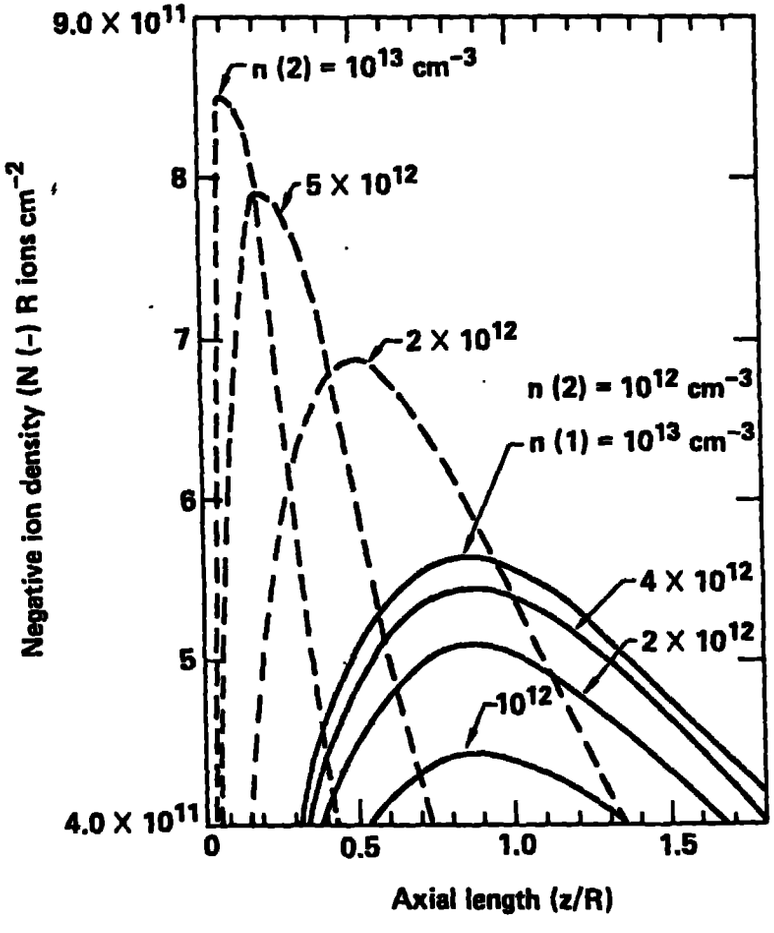
9.0 X 10^11
8
7
6
5
4.0 X 10^11
n (2) = 10^13 cm^-3
5 X 10^12
2 X 10^12
n (2) = 10^12 cm^-3
n (1) = 10^13 cm^-3
4 X 10^12
2 X 10^12
10^12
0
0.5
1.0
1.5
Axial length (z/R)
Negative ion density (N (-) R ions cm^-2

Fig. 2

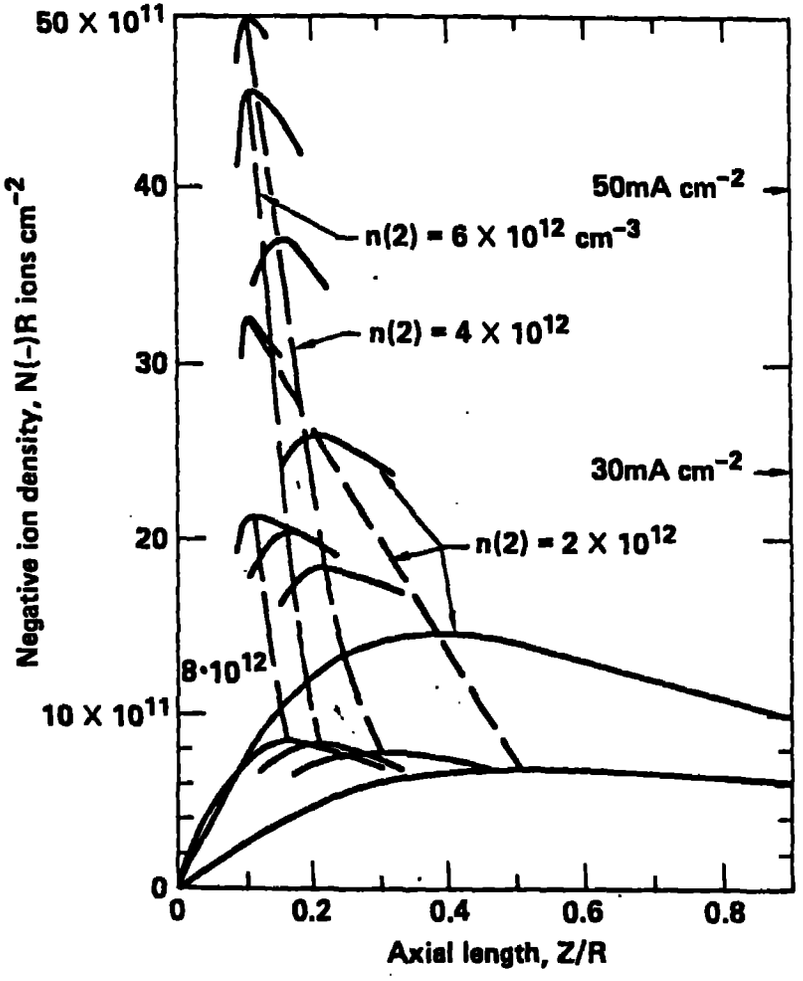
50 X 10^11
40
30
20
10 X 10^11
0
Negative ion density, N(-)R ions cm^-2
50mA cm^-2
n(2) = 6 X 10^12 cm^-3
n(2) = 4 X 10^12
30mA cm^-2
n(2) = 2 X 10^12
8·10^12
0
0.2
0.4
0.6
0.8
Axial length, Z/R

Fig. 3